Operating Life Calculation for Linear Guides

Operating Life

When Linear Guide is loaded in linear reciprocating motion, scaly damages called flaking appear due to material fatigue as the stress works on the rolling elements and rolling contact surfaces constantly. Total travel distance until the first flaking occurs is called Life of Linear Guides.

Rated Life

Rated life is the total travel distance that 90% of linear guides of the same type can reach, under the same conditions, with no occurrence of flaking damage. Rated life can be obtained from the Basic Dynamic Load Rating and the actual load applied on the linear bushings, as shown below.

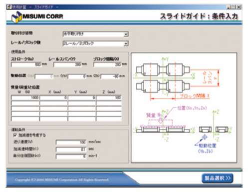
$$L = \left(\frac{C}{P}\right)^3 \cdot 50$$

Load must be calculated before actually using Linear Guides. To obtain load during linear reciprocating motion, it is necessary to fully consider vibration and impact during motion, and also distribution status in relation to Linear Guides. So, it is not easy to obtain load by calculation. Operating temperature also critically affects life. All these conditions considered, the above-mentioned calculation formula is as follows.

$$L = \left(\frac{f_H \cdot f_T \cdot f_C}{f_W} \cdot \frac{C}{P}\right)^3 \cdot 50$$

L : Rated Life (km)
f_H : Hardness Factors (See Fig. 1)
f_T : Temperature Factors (See Fig. 2)
f_C : Contact Factors (See Table-1)
f_W : Load Factors (See Table-2)
C : Basic Dynamic Load Rating (N)
P : Applied Load (N)

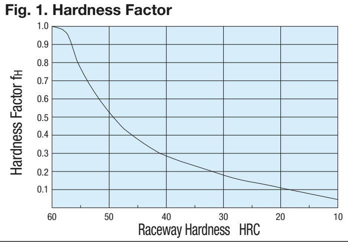
- Operating Life Calculation Software
  MISUMI provides an operating life calculation software for Linear Guides. The life is easily calculated by just entering usage conditions such as load, speed, etc.
  The software can be found at: http://download.misumi.jp/mol/fa_soft.html



• Hardness Factor (f_H)

For Linear Guide applications, sufficient hardness is required for ball contact shafts. Insufficient hardness causes less allowable load, resulting in shorter life.
Please correct the rated life according to the hardness factors.

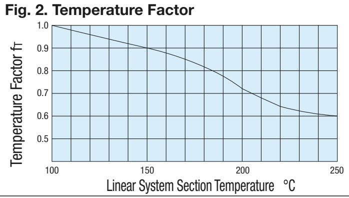
Fig. 1. Hardness Factor



• Temperature Factor (f_T)

If the Linear Guide temperature exceeds 100°C, the Linear Guide and shaft hardness decreases, resulting in less allowable load and shorter life than used at a room temperature.
Please correct the rated life according to the temperature factors.
* Please use Linear Guides under the allowable temperature shown on each product page.

Fig. 2. Temperature Factor



• Contact Factor (f_C)

For actual applications, more than 2 blocks are generally used per shaft. In this case, load applied to each block varies depending on machining precision but is not uniformly distributed. As a result, per-block allowable load varies depending on per-shaft Linear Guide quantity.
Please correct the rated life according to Table-1 Contact Factor.

Table-1. Contact Factor

Number of Linear Guide on One Shaft	Contact Factor fc
1	1.00
2	0.81
3	0.72
4	0.66
5	0.61

• Load Factor (f_W)

To calculate load applied to the Linear Guides, in addition to object weight, it requires inertia force attributed to motion velocity or moment loads. Further, it is necessary to accurately determine the temporal change of each. It, however, is difficult to attain accurate calculations due to potential vibration and impacts caused during reciprocating motion, other than repeated start-stop motions. Table-2 Load Factor helps simplify operating life calculation.

Table-2. Load Factor

Condition of Use	fw
No shocks/vibrations, low speed: 15m/min. or less	1.0~1.5
No significant shocks/vibrations, medium speed: 60m/min. or less	1.5~2.0
With shocks/vibrations, high speed: 60m/min. or more	2.0~3.5

• Applied Load P Calculation Method

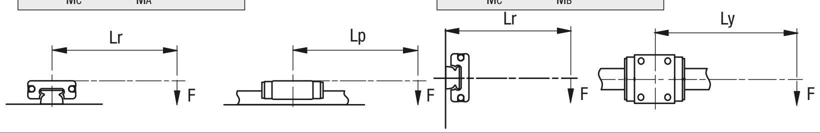
When load is applied to the a block, convert moment load into applied load by the following formula.

· Horizontal Installation

$$P = F + \frac{C_0}{M_C} x (F x L_r) + \frac{C_0}{M_A} x (F x L_p)$$

· Lateral Installation

$$P = F + \frac{C_0}{M_C} x (F x L_r) + \frac{C_0}{M_B} x (F x L_y)$$

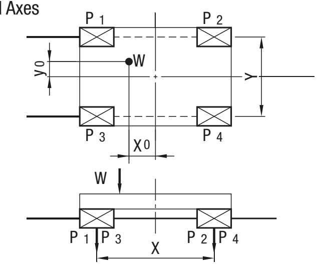
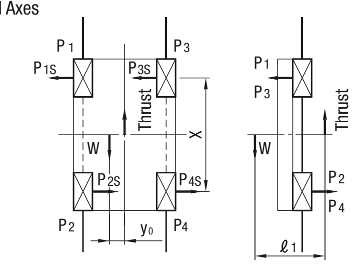
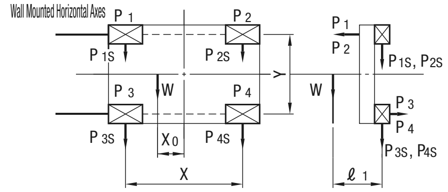
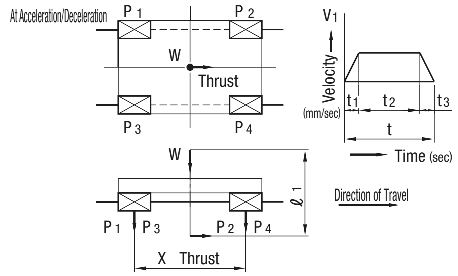


P: Applied Load (N)
F: Downward Load (N)
Co: Static Load Rating (N)
M_A: Allowable Static Moment - Pitch Direction (N • m)
M_B: Allowable Static Moment - Yaw Direction (N • m)
M_C: Allowable Static Moment - Roll Direction (N • m)
Lp: Distance from Block Center to Load Center in Pitch Direction (m)
Ly: Distance from Block Center to Load Center in Yaw Direction (m)
Lr: Distance from Block Center to Load Center in Roll Direction (m)

Load Calculation

Linear Guides perform linear reciprocating motion while supporting object weight. Therefore, load applied to Linear Guides varies depending on the center of gravity of the object, thrust force applied position or changes in speed at start, stop, acceleration and deceleration. For Linear Guide selections, these conditions must be fully considered.

Table-3. Condition of Use and Load Calculation Formula

Classification	Operating Condition and Load
1	Horizontal Axes  $P_1 = \frac{1}{4}W + \frac{X_0}{2X}W + \frac{y_0}{2Y}W$ $P_2 = \frac{1}{4}W - \frac{X_0}{2X}W + \frac{y_0}{2Y}W$ $P_3 = \frac{1}{4}W + \frac{X_0}{2X}W - \frac{y_0}{2Y}W$ $P_4 = \frac{1}{4}W + \frac{X_0}{2X}W - \frac{y_0}{2Y}W$
2	Vertical Axes  $P_1 = P_2 = P_3 = P_4 = \frac{\ell_1}{2X}W$ $P_{1S} = P_{2S} = P_{3S} = P_{4S} = \frac{y_0}{2X}W$
3	Wall Mounted Horizontal Axes  $P_1 = P_2 = P_3 = P_4 = \frac{\ell_1}{2Y}W$ $P_{1S} = P_{3S} = \frac{1}{4}W + \frac{X_0}{2X}W$ $P_{2S} = P_{4S} = \frac{1}{4}W - \frac{X_0}{2X}W$
4	At Acceleration/Deceleration  • When accelerating from a start $P_1 = P_3 = \frac{1}{4}W\left(1 + \frac{2V_1 \cdot \ell_1}{g \cdot t_1 \cdot X}\right)$ $P_2 = P_4 = \frac{1}{4}W\left(1 - \frac{2V_1 \cdot \ell_1}{g \cdot t_1 \cdot X}\right)$ • When decelerating to a stop $P_1 = P_3 = \frac{1}{4}W\left(1 - \frac{2V_1 \cdot \ell_1}{g \cdot t_3 \cdot X}\right)$ $P_2 = P_4 = \frac{1}{4}W\left(1 + \frac{2V_1 \cdot \ell_1}{g \cdot t_3 \cdot X}\right)$ • At constant speed $P_1 = P_2 = P_3 = P_4 = \frac{1}{4}W$ g: Gravitational Acceleration $= 9.8 x 10^3 mm/sec^2$

W : Applied Load (N) P_1, P_2, P_3, P_4: Load applied to Linear Guides (N)
X,Y: Linear Guide Span (mm) V: Travel Speed (mm/sec) t_1: Acceleration Time (sec) t_3: Deceleration Time (sec)

Average of Fluctuating Loads

In general, load applied to Linear Guides varies depending on their applications. For example, there are cases at the start and stop of reciprocating motion, during constant motion or transfer with/without a workpiece. Therefore, it requires average load under which the life equals to the one under these fluctuating loads.

① When load changes in stages according to the distance (Fig. 3)
Travel distance ℓ_1 under load P_1
Travel distance ℓ_2 under load P_2
⋮
For travel distance ℓ_n under load P_n,
average load Pm is obtained by the following formula.

$$P_m = \sqrt[3]{\frac{1}{\ell}(P_1^3 \ell_1 + P_2^3 \ell_2 \cdots + P_n^3 \ell_n)}$$

Pm: Average of Fluctuating Loads (N) ℓ : Total Travel Distance (m)

② When load changes almost linearly (Fig. 4),
average load Pm is approximately obtained by the following formula.

$$P_m \approx \frac{1}{3}(P_{min} + 2 \cdot P_{max})$$

Pmin: Minimum Fluctuating Load (N)
Pmax: Maximum Fluctuating Load (N)

③ When load changes in a sine curve as shown on Fig. 5 (a) and (b),
average load Pm is approximately obtained by the following formula.

Fig. 5 (a) $P_m \approx 0.65 P_{max}$
Fig. 5 (b) $P_m \approx 0.75 P_{max}$

Fig. 3 Staged Fluctuating Loads

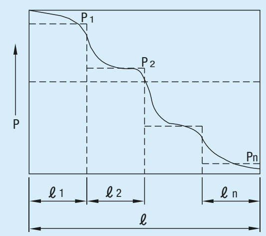


Fig. 4 Constant Fluctuating Loads

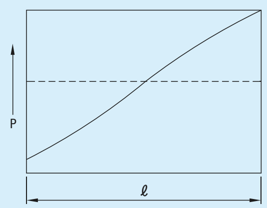


Fig. 5 Sine Curve Formed Fluctuating Loads